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CD/SA 54

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Some Aspects of Shelter and Evacuation Policy to meet H-Bomb threat

1 Introduction

At the present time, with such air raid shelters as are at present in existence and allowing for the planned evacuation of the priority classes, the deaths from a single hydrogen bomb (assumed to have a power a thousand times that of the Nagasaki atomic bomb) on London would be nearly 2½ million, and from five bombs, one each on London, Birmingham, Liverpool, Manchester and Glasgow over 6 million. The first object of Civil Defence must be to prepare a scheme to reduce this figure. No attempt is made in this note to plan such a scheme, but the effect on casualties of certain arbitrary shelter and evacuation measures is discussed in order to indicate the order of magnitude of the reduction which a properly worked out scheme might be expected to achieve.

2 Method of Estimating Deaths

The deaths from a nominal atomic bomb among a population of standard density (43.56 per acre) all in houses have been estimated (CDJPS(EA)(48)14 (Revised)) as 31,000. This is equivalent to everyone within 0.6 miles of the bomb being killed and no one being killed outside this radius. If the generally accepted sealing laws for blast heat and gamma radiation are assumed to apply to hydrogen bombs, then it will be sufficiently accurate for present purposes if we assume that for them everyone is killed within a radius of $0.6 \sqrt[3]{F}$ and no one is killed outside this radius. (Where F is the lower factor of the bomb expressed as a multiple of the lower of the nominal bomb). This assumption ignores the possibility that under certain circumstances there could be a large number of additional casualties due to fall out or radio-active crater debris.

From this and from the known night-time population distribution of our major cities (CD/SA 33), it is a simple matter to calculate the deaths from a bomb of any power on the centre of any particular city.

It must, however, be emphasised that the figures given in this note are deaths only. For the nominal atomic bomb it has usually been assumed that the injured are about equal in number to the killed. For the five hydrogen bombs considered in this note it is fairly certain that the killed would outnumber the injured due to the high population densities in the central (killed) areas as compared with the outer (injured) annuli. However, for the present, no attempt has been made to estimate the number of injured, but in considering the figures given in this note the existence of additional very large numbers of injured must be borne in mind.

3 Deaths with no shelter or evacuation

Table 1 shows the deaths that would result from a bomb with a power of 100N, 500N and 1000N on the centre of each of our five largest cities with no shelter or evacuation.

Table 1

Deaths with no evacuation and no shelter

City	Power of bombs		
	100N	500N	1000N
London	830,000	2,420,000	3,340,000
Birmingham	500,000	1,070,000	1,360,000
Glasgow	780,000	1,180,000	1,330,000
Liverpool	590,000	1,080,000	1,280,000
Manchester	560,000	1,070,000	1,350,000
Total	3,260,000	6,820,000	8,660,000

It will be seen that deaths from the five 1000N bombs total over 8.6 million.

4 Effect of Shelter on deaths

Detailed designs of shelters required to give protection at specified distances from hydrogen bombs of various size, particularly if burst at ground level, have not been worked out. However it is of some interest to see what reduction in deaths would result from shelters of specified performance, even though it is uncertain just what strength and thickness would be required to give that performance. The simplest way of specifying shelter performance is by means of the "Safety Rating" concept developed in CD/SA 48. The safety rating of a shelter was there defined as the saving in life, expressed as a percentage of the deaths without shelter, resulting from the use of the shelter in an area of uniform population density. This shelter with a safety rating of 80 would save 80% of the lives that would have been lost if everyone had been in a house. Put in another way, shelter with a safety rating of 80 would reduce the area within which deaths occurred to one fifth of that for people in houses, and therefore the radius of death to $\frac{1}{\sqrt{5}}$. For a bomb with a power factor of F the equivalent radius of death if everyone is in a shelter with a safety rating of 80 will therefore be $\frac{0.6\sqrt[3]{F}}{\sqrt{5}}$. Similarly for shelter with a safety rating of 90 the radius will be $\frac{0.6\sqrt[3]{F}}{\sqrt{10}}$.

Although, as stated above, the design details of shelters to give these safety ratings have not been determined, it seems probable that surface or trench shelters of rather less than Grade A strength (say 1000 lb/sq.ft.) would be required to give a safety rating of 80, and that a strength of about 2000 lb/sq.ft. would be required for a safety rating of 90. For small street surface shelters the extra cost of an increase in strength of this sort is very small (e.g. the structural cost of a 12"/1000 lb/sq.ft. design is given in CD/SA 48 as £15.2 per person, based on seated capacity) and of a 12"/1400 lb/sq.ft. design as £15.5 per person) and detailed studies may well show that shelters with a higher safety rating than 90 are a practical proposition.

From the formulae for equivalent radii of death given above, and from the population distribution given in CD/SA 33 we can calculate the expected deaths in these two types of shelter under the same conditions of attack as were given in Table 1 for a population all in houses. The results are given in Tables 2 and 3.

Table 2

Deaths with no evacuation but with everyone in a shelter with a Safety Rating of 80

City	Power of bomb		
	100N	500N	1000N
London	135,000	474,000	785,000
Birmingham	129,000	353,000	484,000
Glasgow	223,000	576,000	760,000
Liverpool	159,000	401,000	565,000
Manchester	117,000	386,000	540,000
Total	763,000	2,190,000	3,134,000

Table 3

Deaths with no evacuation but with everyone in a shelter with a Safety Rating of 90

City	Power of bomb		
	100N	500N	1000N
London	59,000	216,000	367,000
Birmingham	64,000	191,000	296,000
Glasgow	115,000	327,000	489,000
Liverpool	78,000	238,000	340,000
Manchester	49,000	186,000	315,000
Total	365,000	1,158,000	1,807,000

It will be seen by comparing Tables 2 and 3 with Table 1 that the reduction in deaths achieved by these shelters decreases with increasing bomb size; thus shelter with a safety rating of 80 reduces deaths by 77% against the 100N bomb, but only by 64% against the 1000N bomb. Similarly the 90% shelter reduces deaths by 89% against the 100N bomb but only by 79% against the 1000N bomb. The reason why these shelters fall increasingly short of their nominal safety rating against bigger and bigger bombs is, because of the lower population density in the outer annuli. For the same reason as the bomb size increases, so does the proportion of the shelter provided which is wasted since the occupants are killed whether they are in shelter or not. This raises the question as to whether, against very large bombs, it is worth while providing shelter in the area immediately round the probable aiming point. The value of any shelter is clearly directly proportional to its chance of saving the occupants from death or injury; if no bomb falls near a particular shelter it is wasted on that occasion because the occupants would have been safe without shelter, and if the bomb falls so close that the occupants are killed anyway, it is for good and all wasted. Thus there exists round any

bomb, for any particular type of shelter, an annulus where people in houses would have been killed or injured, but where shelter would have protected them. In practice, of course, this annulus will not have sharply defined boundaries. Some people closer to the bomb would be saved by shelter and some outside the annulus would have become casualties without shelter, but are saved by it. For the purpose of this preliminary study however, we shall not be too far out if we regard this annulus as having sharply defined boundaries and we shall assume that everyone within it is saved by the shelter.

If we knew exactly what size the bomb was going to be and where it was going to fall shelter policy would therefore be a very simple matter; we should evacuate the people from a circular area round the bomb where it was impossible to provide shelters sufficiently strong to protect them, and we should provide shelters in, and only in, the annulus where people would be killed or injured in houses but where shelters would protect them. Shelters in this annulus would have a "value" of 100%, i.e. they would be certain to save their occupants from death or injury. With the nominal atomic bomb the uncertainty of what aiming point or points the enemy will choose and the expected vagaries of bomb fall about this aiming point, make it not very useful to try to fit our shelter provision to the probable location of this annulus. This is illustrated in Fig.1 which shows the percentage of the shelter provided which actually saves life for shelter with a safety rating of 80 at different distances from the aiming point for four different values of the probable aiming error (P). It will be seen that over the most likely range of P (0.25 miles - 1 mile), this percentage never exceeds 50%. Corresponding curves for the 100N and 1000N bombs are given in Figs. 2 and 3, and the much higher value of shelter (in the right place) for similar aiming errors should be noted.

The considerations discussed above strongly suggest that the right policy against the hydrogen bomb would be to evacuate the central areas of our larger cities and to provide shelter where it is most useful, i.e. in the annulus surrounding the central evacuation area. The optimum size of this central evacuation area clearly depends on the size of bomb likely to be used, and on the standard of protection provided in the shelter annulus; Figs. 2 and 3 suggest that it should have a radius of about $1\frac{1}{2}$ miles for the 100N bomb and about 3 miles for the 1000N bomb if shelter with a safety rating of 80 is provided in the surrounding annulus. As a result of further studies, and of further information about the hydrogen bomb, it may be possible to determine the largest size of bomb likely to be used. If this maximum size of bomb can be determined it will be comparatively simple to determine the optimum size of the central evacuation area for various standards of protection in the surrounding shelter annulus; from this study and from an estimate of the relative "cost" of shelter and evacuation it should be possible to determine the best overall policy.

In the meantime, however, it is of some interest to examine the effect on casualties of an arbitrary evacuation area of radius 5 miles in the case of London and 3 miles in the case of Birmingham, Glasgow, Liverpool and Manchester, in conjunction with shelter having a safety rating of 80 and 90 in the surrounding annulus. In each case the evacuees from the central area are assumed to be accommodated in the surrounding annulus, arbitrarily taken as between 5 and 15 miles in the case of London and between 3 and 7 miles in the case of the other four cities. The factors by which this evacuation would increase the population density in the 'reception' annulus are as follows; London 1.5, Birmingham 1.6, Glasgow 2.5, Liverpool 1.9 and Manchester 1.7. The deaths resulting from an attack with 1000N bombs after this scheme had been implemented are shewn in Tables 4 and 5.

Table 4

Deaths from 1000N bombs after evacuation of 5 mile radius circle for London and 3 mile radius for other cities. Evacuees assumed accommodated in surrounding annulus where they and the original inhabitants are provided with shelter having a safety rating of 80.

City	Position of bomb		
	Central	2 miles from centre	In position to cause maximum deaths
London	0	0	518,000
Birmingham	0	159,000	256,000
Glasgow	0	171,000	247,000
Liverpool	0	174,000	247,000
Manchester	0	164,000	257,000
Total	0	668,000	1,525,000

Table 5

Deaths from 1000N bombs after evacuation of 5 mile radius circle for London and 3 mile radius for other cities. Evacuees assumed accommodated in surrounding annulus where they and the original inhabitants are provided with shelter with a safety rating of 90.

City	Position of bomb		
	Central	2 miles from centre	In position to cause maximum deaths
London	0	0	261,000
Birmingham	0	56,000	155,000
Glasgow	0	64,000	152,000
Liverpool	0	67,000	152,000
Manchester	0	62,000	151,000
Total	0	249,000	871,000

It will be seen from Tables 4 and 5 that, with this scheme of total evacuation of a central area and shelter in the surrounding annulus, a central bomb causes no deaths at all. Clearly, however, the enemy would be aware of our provisions and might well choose to drop his bombs where they would cause maximum casualties. On average, and without allowing for local concentrations which would be bound to occur in the "reception annulus", this would be at about 7 miles from the centre in the case of London and about 4 miles for the other cities. The average deaths from bombs in these worst positions are therefore given in Tables 4 and 5. Comparing these figures with those to Table 1 it will be seen that evacuation plus shelter with a safety rating of 80 has reduced deaths by 82%, and plus shelter with a safety rating of 90 by 90%.

Conclusion

Without shelter or evacuation, the deaths from an attack with only five hydrogen bombs might total over $8\frac{1}{2}$ million. The primary object of Civil Defence must be to reduce this figure. Neither evacuation alone nor shelter alone could reduce these deaths to a manageable proportion, but with a suitable combination of the two, consisting of the total evacuation of the population of the central areas into the surrounding annuli where shelter would be provided, it should be possible to reduce the maximum deaths from this particular attack to something of the order of one million.

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E.L.W.

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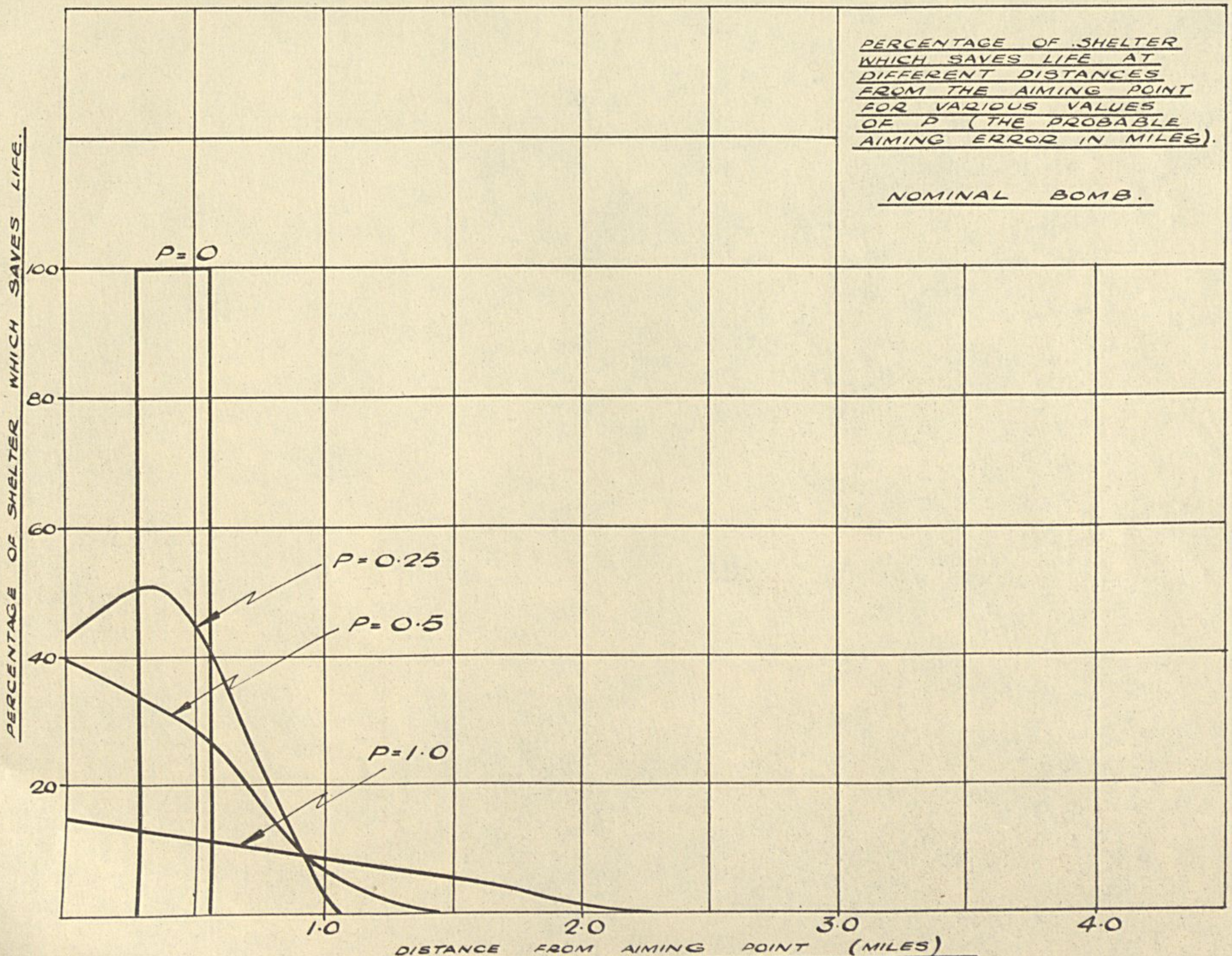

FIG. 1.

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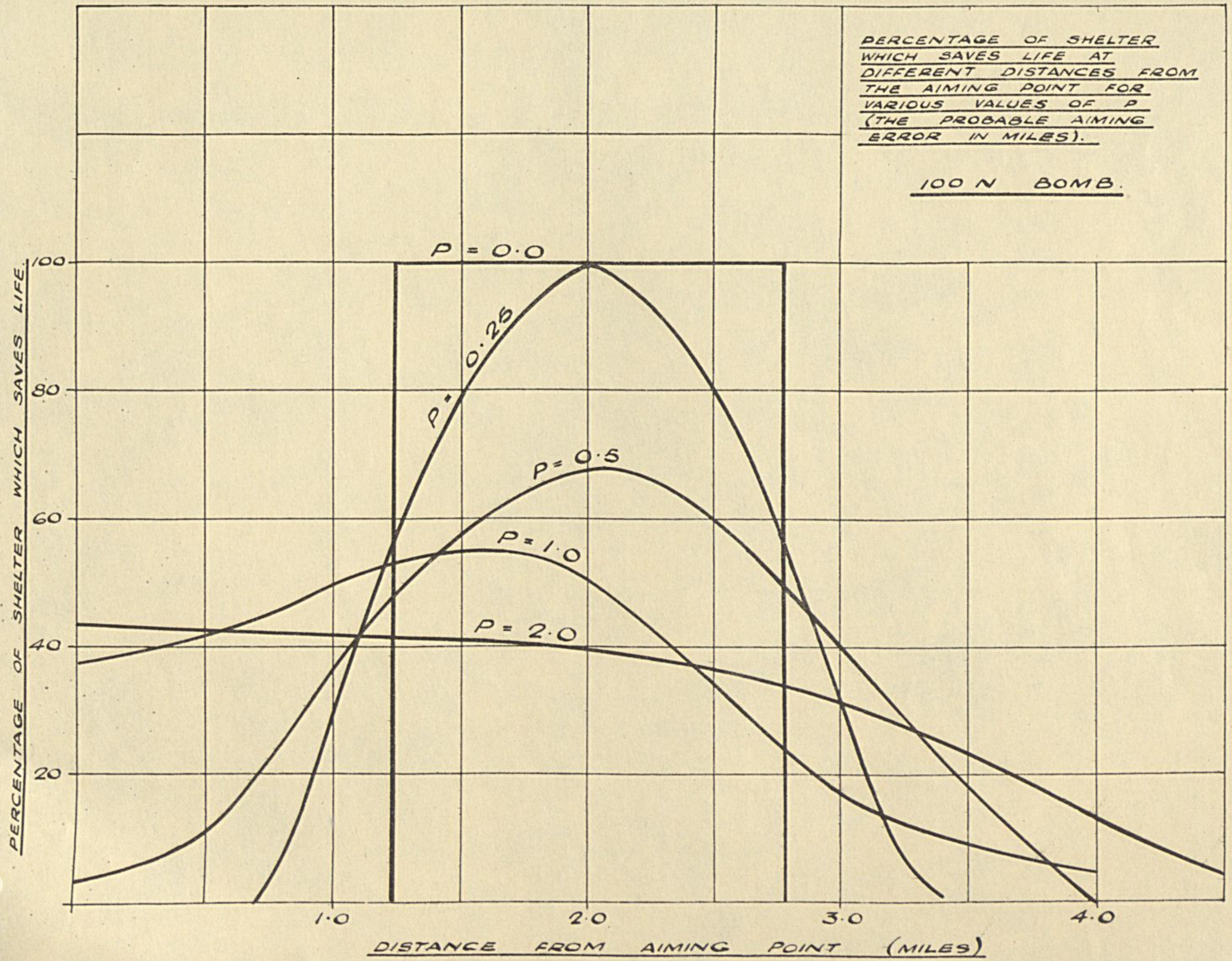

FIG. 2.

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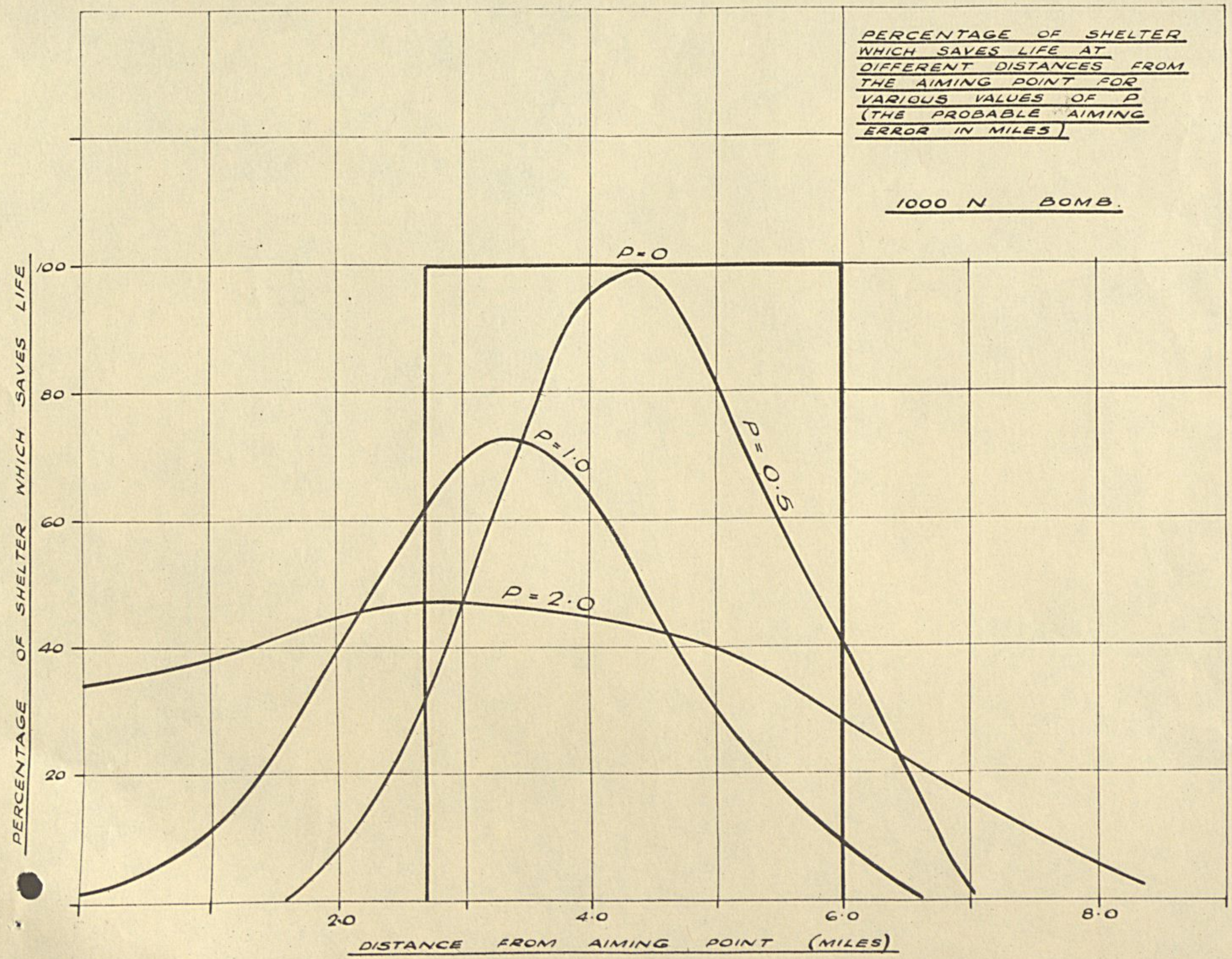

FIG. 3.